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To: NASA Inventions and Contributions Board
RE: “Software of the Year” award

Gentlemen:

I highly recommend that the Data-Parallel Line-Relaxation (DPLR) computational fluid dynamics code be selected for NASA’s Software of the Year award. CUBRC employs the DPLR code as its major computational tool and it is employed daily to support the design and validation of the test programs conducted in the LENS facilities. During the past year, this code has been used in conjunction with our experimental results to provide key aerothermal data to the NASA bipod program, for NASA sponsored studies of leading edge heating and boundary layer transition on the shuttle, and more recently, in studies associated with the MARS Science Laboratory and the Crew Exploration Vehicle. We have also used this program in support of our work with the Army, Navy, Air Force and DARPA in studies of interceptors, scramjet performance, and stage and booster separation.

While our work in the LENS facility is based mainly on experimental work, during the past several years we have generated an integrated approach employing the best numerical tools (DPLR) to support the design and validation of the test facilities, to aid in the design of the models and placement of the instrumentation for the test programs, and the validation of the measurements made in the facilities both in the freestream and around the models. So tight is this integration that we would not think of conducting any facility improvement or running any test program without first employing numerical simulations of the fluid dynamic characteristics using DPLR and the structural and vibrational characteristics using state-of-the-art structural codes.

First, and most fundamentally, we use CFD to validate the facilities themselves. Testing at high enthalpy offers many obstacles that lower energy facilities avoid, and one of the most challenging is insuring that the facility is running correctly and that the freestream conditions produced over the model are known. We do extensive calibrations and diagnostics with basic configurations (hemispheres, cylinders, cones, etc) that are all verified with DPLR. We have had marked success in matching the results obtained over a wide range of enthalpies, Reynolds numbers, and test gases with the predicted results from DPLR.

CFD is also used in the design process for each program, where we do basic calculations before a model is even constructed. This allows us to place aerothermal instrumentation in the correct locations to study detailed flow features, insure that conditions are right to target the primary objectives of the test, and place the model in the correct location in the tunnel to insure it is contained inside the uniform core of the freestream flow. This has allowed us to place some very large models such as HyFly, the 3.5% Shuttle OTS, and a 24" diameter sphere-cone shell into our facilities with confidence that we will obtain quality data.

During and after a test program, we use DPLR in near real-time with the facilities to validate each unique run as the data is processed. Depending on conditions, LENS can typically make two to three runs per day. We use the DPLR code to check at least some part of this data to insure that the run was good. For instance, during the aeroheating tests on the shuttle bipod (which was on the critical path for the return-to-flight), we used DPLR to check the attached heat transfer and pressure on the forebody of the main tank. DPLR is as much as one order of magnitude faster to converge than most commercial CFD codes, so each case could be completed in a couple of hours. This allowed us to make the decision that a run was good before moving on to the next condition. With a slower code that could only solve three or four cases per week, this real-time feedback would have been impossible.

Although it is important to be fast and robust, the single most important feature of DPLR is that it be accurate. We continue to use DPLR because it has continued to provide us with very accurate answers for a wide range of phenomena and geometries. Even for attached turbulent flows, we have obtained good agreement with many cases. Although there are phenomena in hypersonics that are not well-modeled by any algorithms yet developed, DPLR always provides us with some direction about each problem. Few codes have the physical models and quality numerics required to simulate the flows in a hypervelocity shock tunnel, but our experience has shown that we can rely on it to provide us with the guidance to make informed decisions about our experiments.

In summary, we employ the DPLR code as our primary computational tool which we have found to be fast, accurate, and most of all reliable. In the future, we plan to continue the use of this code and work with NASA in areas where our experimental facilities can make unique contributions in hypervelocity, high Reynolds numbers turbulent flows where the physical models of turbulence, chemistry, and combustion employed in the codes can be evaluated and improved.

Sincerely,

Michael S. Holden, PhD
Program Manager

MSH/am